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## ABSTRACT

Information on the development and testing of a model of spatial diffusion and adoption of an agricultural innovation is presented. The data concern the practice of artificial insemination of cattle in southern Sweden. The model is intended to predict the time at which adoption occurred in terms of the time at which the innovation became available in the adopter's neighborhood, the time at which the adopter first heard about the innovation, and the adopter's set of personal acquaintances, age, and economic status. Eighteen critical variables are used in the model, including availability and cost of the innovation, projected benefits, existence of a support infrastructure, agricultural income of the farmer, and size of the farmer's herd. Test results show that the innovative farmers were consistently difficult to classify and that the linear relationship, which was broadly applicable to the early majority adopters, late majority adopters, and laggards, was inapplicable to them. The need for further research on models of this type is indicated. References are included. (Author/DB)

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A MODEL OF THE ADOPTION AND DIFFUSION OF INNOVATIONS FOR THE CASE  
OF THE INDIVIDUAL DECISION-MAKER

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ABSTRACT. A model of the spatial diffusion and adoption of an agricultural innovation is developed and tested, using data on the spread of artificial insemination of cattle amongst farmers in southern Sweden. The model, which consists of a system of equations, is aimed at the level of the individual adopter. It is intended to predict the time at which adoption occurred in terms of the time at which the innovation became available in the adopter's neighborhood, the time at which the adopter first heard about the innovation, and the adopter's set of personal acquaintances, age and economic status.

This paper presents a model of the spatial diffusion and adoption of an agricultural innovation, together with a test of the model using data on the spread of artificial insemination of cattle amongst farmers in southern Sweden. The model, which consists of a system of equations, is aimed at the level of the individual adopter and is intended to predict the time at which adoption occurred. It incorporates several factors that have previously been shown to influence such a decision, including the important one of the provision and availability of the innovation for potential adopters.

An extensive review of previous research in this area will not be provided here, since several are available (see, for example, Brown and Cox, 1971). It is worth noting, however, that the majority of this research has been concerned with explaining diffusion from the point of view of individual adoption behavior. Until recently, there has not been much concern

with the provision of innovations (see, however, Brown, 1975). Of the former type, two broad thrusts can be identified. One is concerned with defining spatial trends or stages in diffusion with respect to centers in space. This work is exemplified by Hagerstrand's earlier research into primary, diffusion and condensing stages of diffusion (Hagerstrand, 1952; but also see Morrill, 1968 and Hanham and Brown, 1976). The other utilizes and evaluates the assumption of interpersonal communication as the major factor that influences adoption and hence diffusion (see Hagerstrand, 1967; Rogers, 1971; and Blaikie, 1973, for example).

The behavior of potential adopters may be influenced by the decision-making behavior of propagator or agent in several ways. First, the time at which a potential adopter can adopt will be constrained by the time and place in which the agency is established. Its location must be such that the potential adopter will become aware of the innovation and perhaps be able to travel there in order to obtain it. Second, adoption behavior may be influenced by the publicity strategy (or lack of it) of the agent. Third, it may be influenced by the extent to which the agent controls the diffusion of other innovations that are necessary for the adoption of the primary one. This is an important distinction, and will be discussed in more detail. Many innovations require potential adopters to adopt supporting innovations or infrastructure before they themselves can be satisfactorily adopted.

From the potential adopter's point of view, the critical factor as to whether he will adopt the primary innovation is the availability and cost

of such supporting innovations. The simplest case is that of the dichotomy between availability and unavailability, where the former implies a relatively low cost imposed upon the adoption of the primary innovation and the latter implies an exorbitant cost, which renders adoption of the primary innovation impossible. Should the supporting innovations be available, any spatial variability in the costs of adopting them will probably be reflected by the spatial variability of the adoption of the primary innovation.

The agent or propagator can therefore have varying influence upon adoption behavior, depending upon his ability to control the diffusion of such supporting innovations and infrastructure. Not only might the agent be able to influence adoption by making this infrastructure available, he may also be able to influence the cost of it to the potential adopter. For example, he may subsidize the collection and transportation of a cash crop or levy a fixed price for the services of a specialist or energy required for another innovation.

It appears reasonable to assume that the utility to the agent of influencing the direction of diffusion in various locations, say through the provision of supporting innovations or infrastructure, will depend upon his perception of the costs and benefits that will be derived from the adoption of the primary innovation in each location. Furthermore, the perceived costs are likely to increase with distance from the agent's location and so are, provided his familiarity with potential locations and information is spatially biased, the perceived benefits. As a result, it is more

likely that the agent will first provide supporting innovations or infrastructure in the vicinity of his own location. Perhaps as his perceived utility of doing so increases, he will proceed to extend this provision. To some extent this extension will be tempered by his previous experience. In a spatial context, we may conceive of this infrastructure being extended outward from a point, either in a stepped or approximately continuous fashion.

#### DIFFUSION IN SOUTHERN SWEDEN

The diffusion of the artificial insemination of cattle amongst farmers in the southwest Skane region of Sweden since 1944 is one example of the diffusion of an innovation which requires supporting infrastructure before it can be adopted. The Kavlingeortens Seminfoining was one of several regional associations devoted to the spread of artificial insemination of cattle. It was established in Kavlinge, Malmohus Lans, in 1944. This association will be regarded as a agency within the context of the previous discussion. As such, it provides the supporting infrastructure, in the form of authorized veterinarians capable of implementing this service, necessary for the adoption of artificial insemination by the farmers in the region. The veterinarians are supplied from the agency's location.

From 1944 onwards, the adoption of this innovation spread systematically away from its origin at Kavlinge (Hanham and Brown, 1976). A sample of 562 farmers in the vicinity of Horby (which is to the east of Kavlinge) enables us to trace the diffusion in some detail in one area. The first of the farmers to adopt did so in 1946, and these seven are located in the

south of the sample area. The major thrust of the spread of the innovation for any given year is illustrated in figure 1. Up till 1953 it spread gradually northward, so that by the end of that year, it had reached the periphery of the region. From 1954 to 1964, others continued to adopt, but these were generally located amongst those who had previously done so. It is assumed that the diffusion from south to north was largely in response to the provision or availability of the artificial insemination service rather than interpersonal communication. It seems unlikely that it took eight years for the news of this innovation to spread between 20 and 30 kilometers in an area such as this. This is not to suggest that information did not play an important role in adoption, but rather that it must be viewed within the constraints of the availability of the innovation.

To test these and other expectations regarding the adoption and diffusion of this innovation, a detailed set of data for a subsample of 127 farmers was used. The 18 variables used in this study have been listed in Table 1. Amongst these are variables depicting the time at which the farmer not only adopted (AY), but when he first heard about the innovation (FH) and when the innovation first appeared in his neighborhood (FN). There are also variables relating to the farm (farm size, FM; size of herd, CW), its location and character of the neighborhood (distance to Kavlinge, DK; density of farmers, DN), the farmer's economic status and commitment to farming (agricultural income, IN; the ratio of this income to total income, RA), membership in a bull association (BL; such associations were prominent before the introduction of artificial insemination and provided a similar service), the farmer's age at adoption (AG) and the farmer's travel behavior or ex-

posure to communication (number of acquaintances in the region, AQ; typical phone bill, PH; number of monthly trips to the local market center, TH; possession of a car, CR; subscription to a local newspaper, Stockholm newspaper or agricultural journal, LC, ST, and AJ).

#### THE MODEL OF ADOPTION

The model used to predict time of adoption is illustrated in Figure 2, and consists of the following equations:

$$(1) \text{ FN} = \text{FN} (\text{DN}, \text{DK}) = a + b_1 \text{ LN} + b_2 \text{ DK} + e$$

$$(2) \text{ FN} = \text{FH} (\text{FN}, \text{CR}, \text{AJ}, \text{PH}, \text{LC}, \text{ST}, \text{TH}, \text{BL}) \\ = a + b_1 \text{ FN} + b_2 \text{ CR} + b_3 \text{ AJ} + b_4 \text{ PH} + b_5 \text{ LC} + b_6 \text{ ST} + b_7 \text{ TH} + b_8 \text{ BL} \\ + e$$

$$(3) \text{ IN} = \text{IN} (\text{CW}, \text{RA}, \text{FM}) = a + b_1 \text{ CW} + b_2 \text{ RA} + b_3 \text{ FM} + e$$

$$(4) \text{ AY} = \text{AY} (\text{AG}, \text{AQ}, \text{FH}, \text{IN}) = a + b_1 \text{ AG} + b_2 \text{ AQ} + b_3 \text{ FH} + b_4 \text{ IN} + e$$

Equation (1) suggests that the time at which the innovation became available in the adopter's neighborhood depends upon the density of farmers in that neighborhood and how far it is from the headquarters in Kavlinge. These two are surrogates for the perceived benefits and costs associated with making the innovation available on the part of the propagator. Equation (2) predicts the time at which the adopter first heard about the innovation in terms of his potential for exposure to such information. As such, the following variables are included - the time at which the innovation became available in his neighborhood, his average monthly trips to the local market center, whether he owned a car, his average phone bill, whether he subscribed to a local newspaper, Stockholm newspaper and agricultural journal

and finally, whether he was a member of a bull association. Some of these variables refer to information via mass media, others via personal communication and demonstration effects. Membership of a bull association was included, since it is thought likely that such members were the target of advertising concerning artificial insemination.

Agricultural income is assumed to be dependent upon the size of the farm, size of herd and the degree to which that income forms a part of the farmer's total income (for part-time farmers, this proportion becomes quite small). This is represented by equation (3). The final one, (4), predicts the time of adoption in terms of the time at which he first heard, his agricultural income, his age and the number of acquaintances he has in the region. The latter variable is intended to reflect the degree of reinforcement the farmer may have, after first hearing about the innovation. Age and income status are intended to reflect the degree of tradition and willingness to take risk.

The parameters of equations 1 through 4 were estimated by least squares procedures. Where the endogenous variables FN, FH and IN were used as independent variables in equations 2 and 4, their values predicted on the basis of equations 1, 2 and 3 were employed rather than their actual values, i.e.  $\hat{FN}$ ,  $\hat{FH}$  and  $\hat{IN}$ . The resulting equations, showing only those parameters significantly different from zero at the 5 percent level using a t test as criterion, together with multiple correlation and standard errors in parentheses are as follows:

$$R = .70$$

$$(1a) \hat{F}_N = 47.64 - 0.25 DN + 0.003 DK$$

$$(0.042) \quad (0.00088)$$

$$R = .56$$

$$(2a) \hat{F}_H = 25.37 - 1.64 CR - 2.77 AJ - 0.012 PH + 0.61 FN$$

$$(0.81) \quad (0.73) \quad (0.0059) \quad (0.14)$$

$$R = .66$$

$$(3a) \hat{I}_N = -2420.77 + 360.69 CW + 11791.72 RA$$

$$(66.74) \quad (1764.71)$$

$$R = .59$$

$$(4a) \hat{A}_Y = 12.22 - 0.00016 IN + 0.95 FH$$

$$(0.00008) \quad (0.12)$$

The right hand side of equation (1a) can be substituted for  $\hat{F}_N$  in equation (2a) and, likewise, the right hand side of equation (2a) and (3a) can be substituted for  $\hat{F}_H$  and  $\hat{I}_N$  respectively in equation (4a). This produces the following two equations:

$$(2b) \hat{F}_H = 54.43 - 1.64 CR - 2.77 AJ - 0.012 PH - 0.15 DN + 0.0018 DK$$

$$(4b) \hat{A}_Y = 58.87 - 0.058 CW - 1.89 RA - 1.39 CR - 2.35 AJ - 0.0102 PH$$

$$+ 0.0015 DK - 0.13 DN$$

Equation (4b) therefore predicts the time of adoption in terms of a set of exogenous factors reflecting the availability of the innovation, exposure to communication and characteristics of the farming operation.

In general, the model has done well in predicting adoption, particularly when we consider the fact that we are concerned with data at the individual

scale. It is far harder to account for the variation in the behavior of individuals than it is for aggregates of individuals. In all those cases in which a variable was retained (possessed a significant coefficient), the coefficient had the expected sign. The farmers who adopted earlier were those who heard about the innovation earlier and who had larger agricultural incomes. Those who had larger incomes had larger herds of cattle and gained most of their income from agriculture. Those farmers who heard earlier were those who possessed a car, subscribed to an agricultural journal, used a phone more and in whose neighborhood the innovation became available at an early date. The innovation became available earlier in those neighborhoods with a higher density of farmers and those located closer to Kavlinge.

Of those that did not enter the final equations, the following stand out; the time at which a farmer first heard did not depend upon the fact that he made more trips in the region, subscribed to a local or national newspaper or was a member of a bull association. The time of adoption did not appear to depend upon the farmer's age nor upon the number of acquaintances he had in the region. We shall see at a later stage that this result is actually misleading, particularly as there are non-linear relationships involved here.

An alternative model to equation (4) was also evaluated, namely a linear discriminant function. The purpose of this model was to predict which adopter category each farmer belonged to on the basis of the four variables:  $A$ ,  $AN$ ,  $AQ$ , and  $AG$ . In line with previous studies of this nature, four categories were employed, namely innovators, early majority, late majority and

laggards, and in which there were 14, 42, 34 and 37 members respectively. In common with the regression analysis, only  $\hat{F}$  -  $\hat{IN}$  significantly contributed to the discriminant function using the F ratio at the 5 percent level as the criterion. The intergroup F matrix and the classification that resulted from the significant function are presented in Tables 2 and 3. The latter indicates the percent of farmers from each (row) category that were classified in each adopter category.

The intercategory F ratios and the accuracy in the classification of farmers in each adopter category testifies to the ability of the discriminant model. The intercategory F ratios are progressively higher as the difference between categories increases. The classification of the farmers in appropriate categories is not uniformly successful, there is greater accuracy in some than others. No category, however, places a higher percentage in an incorrect rather than the correctly predicted one. Some incorrectly predicted farmers do suggest some interesting deviations from the model, some of which may be attributed to the existence of non-linear relationships in the problem at hand.

#### SOME CAUTIONS

Although the relationships that were uncovered by estimating the parameters of the model appear quite plausible, the seeming insignificance of others is actually misleading. The major reason for this is the existence of several non-linear relationships exhibited by the data. Following Wilkie's advice, such relationships were explicitly sought after by cross-tabulating the year of adoption with each of the remaining variables (Wil-

kie, 1974). Figure 4 presents the proportion of farmers in each adopter category who owned a car, was a member of a bull association and who were in one of three age groups as examples of these relationships. In the first case, the proportion of adopters who were car owners does increase systematically for earlier categories, with the exception of innovators, who have a smaller proportion than would be expected on the basis of a simple linear relationship. In the second case, the proportion of adopters who were members of a bull association decreased for earlier categories, with the exception of innovators, where the reverse is clearly evident. In the third case, the proportion of adopters who were classified as young when they adopted increased and the proportion classified as old decreased for earlier categories, with the exception of innovators, who were clearly dominated by the middle-aged and, to a lesser extent, by the older.

These three examples alone suggest that although linear relationships may be broadly applicable to the early majority, late majority and laggard categories, they are not for innovators. The latter are consistently deviant. Attention is currently being directed to uncovering the reasons for these non-linearities and to employing multidimensional contingency tables to model these relationships. Finally, another problem that is being tackled, is the task of modeling a causal system that is clearly not recursive, an assumption that was imposed on the model presented in this paper.

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TABLE 1  
LIST OF VARIABLES USED IN THE MODEL

| Code name | Definition                         |
|-----------|------------------------------------|
| AY        | year of adoption                   |
| AG        | farmer's age at adoption           |
| AQ        | number of acquaintances            |
| AJ        | sub. to agricultural journal       |
| CR        | possesses a car                    |
| PH        | average phone bill                 |
| FN        | date first neighbor adopted        |
| FH        | date adopter first heard           |
| IN        | agricultural income                |
| CW        | size of herd                       |
| RA        | agric./total income ratio          |
| DN        | density of farmers in neighborhood |
| DK        | distance to Kavlinge               |
| FM        | size of farm                       |
| BL        | membership of bull association     |
| LC        | sub. to a local newspaper          |
| ST        | sub. to a Stockholm newspaper      |
| TH        | average monthly trips to Horby     |

TABLE 2

INTERCATEGORY F RATIOS FROM THE DISCRIMINANT MODEL

|       | INNOV | EARLY | LATE  | LAGGS |
|-------|-------|-------|-------|-------|
| INNOV | -     |       |       |       |
| EARLY | 4.53  | -     |       |       |
| LATE  | 5.73  | 12.02 | -     |       |
| LAGGS | 25.81 | 27.30 | 17.18 | -     |

TABLE 3

PERCENT OF ADOPTERS CLASSIFIED BY THE DISCRIMINANT  
FUNCTION INTO EACH CATEGORY (BY ROW)

| ORIGINAL | PREDICTED |       |      |       |
|----------|-----------|-------|------|-------|
|          | INNOV     | EARLY | LATE | LAGGS |
| INNOV    | 72        | 0     | 21   | 7     |
| EARLY    | 26        | 55    | 7    | 12    |
| LATE     | 21        | 18    | 38   | 23    |
| LAGGS    | 3         | 13    | 22   | 62    |

|             |        |               |              |        |
|-------------|--------|---------------|--------------|--------|
| OWNS<br>CAR | 79     | 88            | 67           | 56     |
| NO<br>CAR   | 21     | 12            | 33           | 44     |
|             | INNOV. | EARLY<br>MAJ. | LATE<br>MAJ. | LAGGS. |

|                       |        |               |              |        |
|-----------------------|--------|---------------|--------------|--------|
| MEMBER<br>BULL ASSOC. | 85     | 5             | 44           | 19     |
| NOT A<br>MEMBER       | 15     | 95            | 56           | 81     |
|                       | INNOV. | EARLY<br>MAJ. | LATE<br>MAJ. | LAGGS. |

|                |        |               |              |        |
|----------------|--------|---------------|--------------|--------|
| OLD            | 21     | 7             | 23           | 44     |
| MIDDLE<br>AGED | 79     | 70            | 67           | 44     |
| YOUNG          | 0      | 23            | 10           | 12     |
|                | INNOV. | EARLY<br>MAJ. | LATE<br>MAJ. | LAGGS. |

Table 4: Cross-tabulation of year of adoption with car ownership,  
membership in bull association and age of adoption.  
(percentages by columns)

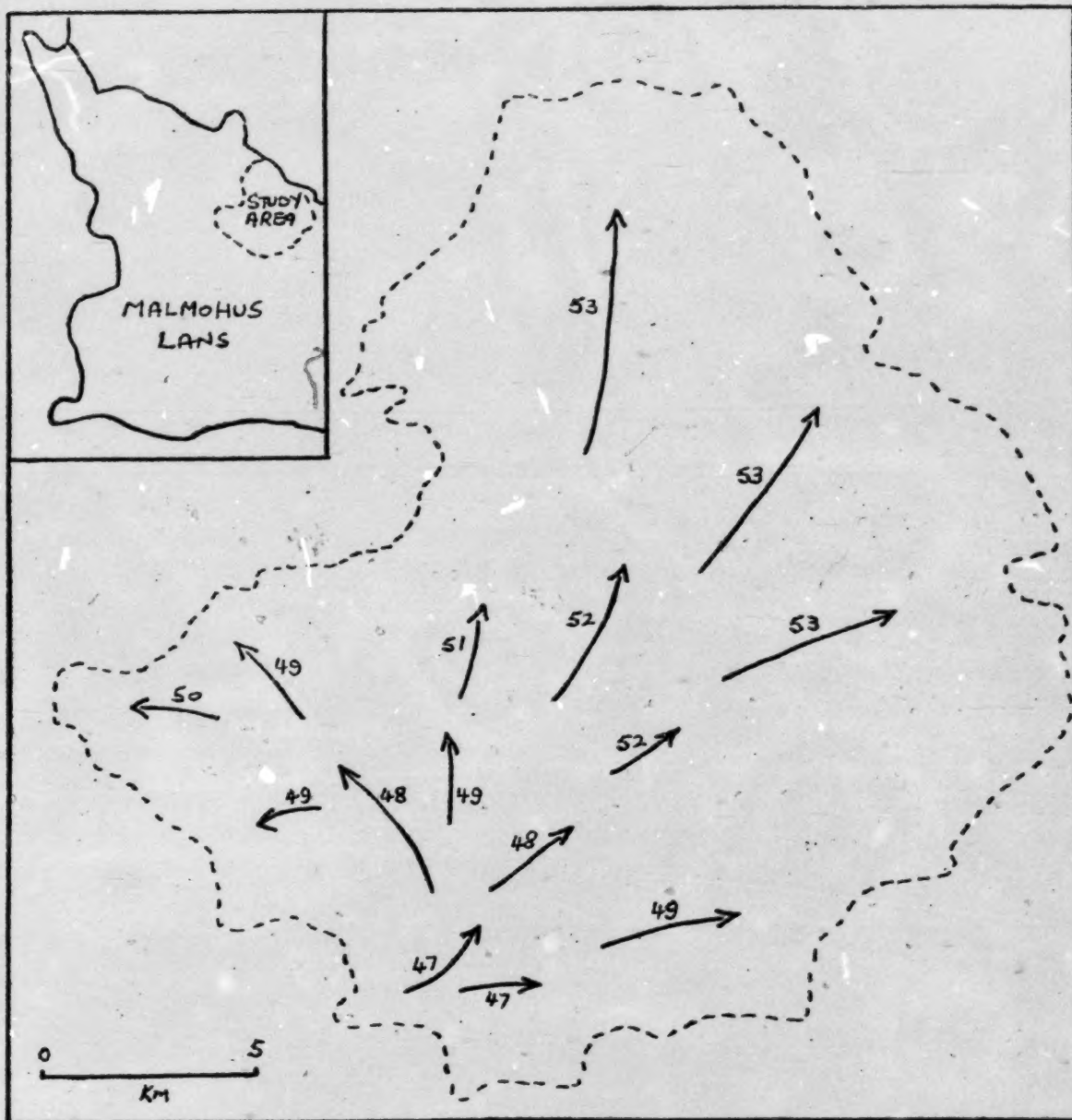


Figure 1 : The spread of artificial insemination of cattle amongst farmers in the study area

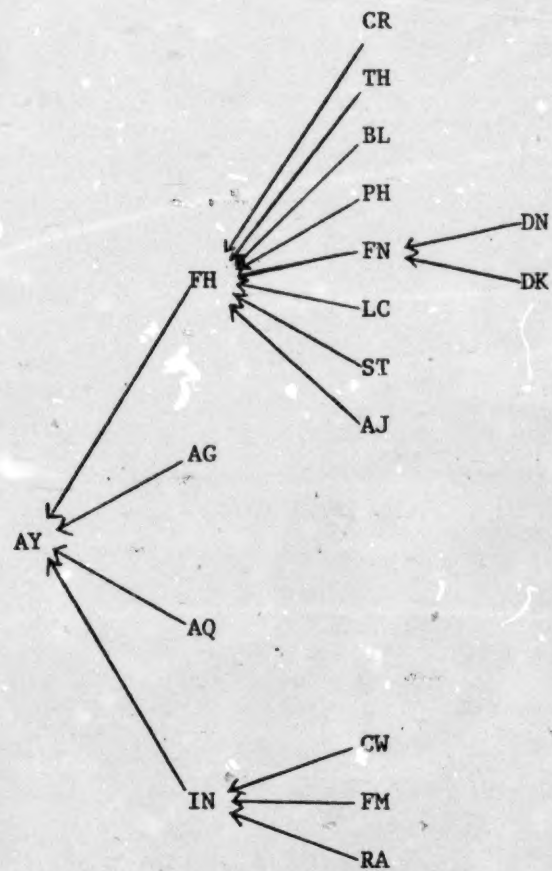


Figure 2: Diagrammatic form of the adoption model